Small scale water disinfection for military purposes.

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1. SUMMARY

When a military force is in the field, it is impossible to apply at all times the normal practices of water purification such as coagulation, flocculation, sedimentation, filtration and chlorination used for a municipal water supply. For personnel who are separated from their units and for whom it is impractical to use a water point, individual water treatment tablets are issued for water disinfection.

The Materials Research Laboratory at Scottsdale, Tasmania has for many years been involved in the development and evaluation of individual and small scale water disinfection systems. Described are laboratory evaluations of several devices for small scale water disinfection.

2. INTRODUCTION

Troops in the field must have access to potable water. Absence of such a supply leads to the risk of gastroenteritis, amoebic dysentery or bacillary dysentery. It has been said that more people died of bacillary dysentery in the US civil war than were killed in battle. It was also a problem in World War I when, for instance, it was a significant element in the outcome of the battle for Gallipoli. In World War II bacillary dysentery was a problem especially in the South Pacific and Mediterranean areas (Burrows, 1963). There are also reports of amoebic dysentery affecting thousands of troops in Vietnam (Stringer, Cramer & Krusé, 1977).

In static situations water is taken from an available source, treated by the engineers using standard water purifying equipment, and made available to the soldier without further treatment. For personnel who are separated from their units and for whom it is impractical to use a water point, individual iodine water treatment tablets are issued for water disinfection.

Prior to 1969 the tablet outfit consisted of a sterilising tablet (chloramine-T) and a detasting/neutralising tablet (sodium thiosulphate). Although the two tablets were colour coded they could be added in the incorrect order; or the detasting tablet after insufficient contact time for the chloramine-T; or even both at the same time. The neutralising tablet was therefore removed from the kit. An iodine based tablet (*Afses*) was developed by MRL-Tasmania and introduced in 1972, after trials established that the chloramine-T tablets were ineffective biocides. In the *Afses*, iodine was formed from potassium iodide, potassium permanganate and potassium iodate. The Director General Army Health Services recommended suspension of *Afses* in 1980 because of possible health hazards due to ingestion of excess iodine. *Puritabs* containing sodium dichloroisocyanurate, which dissociates in water to give sodium cyanurate and hypochlorous acid (10 ppm), were introduced as an interim measure.

MRL-Tasmania evaluated water sterilising tablets and in 1985 recommended

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13 ABSTRACT(MAX 200 WORDS) WHEN A MILITARY FORCE IS IN THE FIELD, IT IS IMPOSSIBLE TO APPLY AT ALL TIMES THE NORMAL PRACTICES OF WATER PURIFICATION SUCH AS COAGULATION, FLOCCULATION, SEDIMENTATION, FILTRATION AND CHLORINATION USED FOR MUNICIPAL WATER SUPPLY. FOR PERSONNEL WHO ARE SEPARATED FROM THEIR UNITS AND FOR WHOM IT IS IMPRACTICAL TO USE A WATER POINT, INDIVIDUAL WATER TREATMENT TABLETS ARE ISSUED FOR WATER DISINFECTION.
THE MATERIALS RESEARCH LABORATORY AT SCOTTSDALE, TASMANIA HAS FOR MANY YEARS BEEN INVOLVED IN THE DEVELOPMENT AND IN THE EVALUATION OF INDIVIDUAL AND SMALL SCALE WATER DISINFECTION SYSTEMS. DESCRIBED ARE LABORATORY EVALUATIONS OF SEVERAL DEVICES FOR SMALL SCALE WATER DISINFECTION.

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the introduction of *Potable Aqua* (Thomson, James, Driver and Hancock, 1985).

To many military personnel, the use of water sterilising tablets is just one more unnecessary action. This is compounded by a dislike of the medicinal taste of tablet treated water. When this is considered in conjunction with the requirement to drink up to 20 L per day in hot climates the risk of water borne disease outbreaks is high.

This paper outlines evaluations of the Ecomaster range of devices which have been considered in an attempt to overcome the palatability problems.

The Ecomaster range of products use combinations of the following constituents: (i) pentaiodide resin (I_5); (ii) activated carbon (c); (iii) triiodide resin (I_3). The I_5 and I_3 resins were developed at Kansas State University in Manhattan, Kansas (Marchin, Fina, Lambert and Fina, 1983). The resins were initially formulated to disinfect relatively 'clear' water on board Skylab and the Shuttle of the U.S. space program. Iodine disinfection replaced chlorine, which was used in the Apollo program, because of its superior disinfecting ability as well as its relatively low reactivity with metal alloys (Marchin, 1990). Triiodide has been used in the Shuttle spacecraft to disinfect water generated by the fuel cells. Since the water was of high quality, iodine addition was mainly concerned with preventing microorganism colonisation during storage in on-board reservoirs (Marchin, 1990). The pentaiodide resin was developed in response to a perceived need to use spacecraft for long periods of time with recycling of water through various systems. Marchin (1990) felt that this would require a more potent biocide than the triiodide resin.

The activated carbon was incorporated to reduce the level of ingested iodine and also would serve to improve palatability. The I_3 was incorporated after the carbon to reduce the possibility of processed water becoming contaminated by microorganisms which may colonise the carbon. This colonisation might occur through back siphonage. The I_3 also removes residual I_2 molecules which are eluted from the pentaiodide resin (Marchin, 1990).

3. MATERIALS & METHODS

3.1 Biocidal Efficiency

The efficiency of kill of each tablet or device was estimated using water containing *Staphylococcus aureus* NCTC 6749, *Pseudomonas aeruginosa* NCTC 6749 and *Escherichia coli* NCTC 8196. The inoculated matrix was prepared by addition of 0.5 Ml of an overnight culture of each organism in nutrient broth medium, per litre of water. The final concentration of bacteria was approximately 10^6 Ml^{-1}. The water used was either deionised water or a simulated contaminated water (SCW). The SCW (Table 1) was developed so that the sterilising tablets could be evaluated under reproducible conditions which simulate those found in natural waters. SCW as used has an iodine demand equivalent to 2.6 mg/L iodine. The ammonium ion was included since it is common in water and has complexing properties. This ion along with the phosphate ion also serve as buffering ions. The tartrate ion was included to represent the carboxylic acids likely to be present in water as part of the humic acids, this particular acid has oxidising - reducing properties. L-cysteine was included as a sulphydryl bearing compound to represent the sulphydrl groups likely to be present in the humic acids and it also has oxidising reducing properties. L-cysteine is also an amino acid and will represent this group of compounds. Sodium, potassium, chloride and sulphate ions are included as ions commonly present in water. Starch is included as it

forms an interstitial complex with iodine, and to simulate complex carbohydrates.

Table 1: Formulation of Simulated Contaminated Water (SCW).

Compound	mg/L
$Na_3PO_4.12H_2O$	81.2
NaK Tartrate	40.4
L-Cysteine	10.4
Starch (soluble)	1.0
$(NH_4)_2SO_4$	9.4
NaCl	53.8

The Standard Plate Count (SPC) method as described in AS 1095 (1971) was used to determine the total number of viable bacteria present. The active agent of each treatment was neutralised after its specified contact period, with 5% (w/v) sodium thiosulphate solution (W.H.O. 1978).

The Logistic Command Interim Specification for Water Purifying Tablets (LCIS, 1975) requires a 99.9% kill rate for total viable bacteria, when tested as described above with DIW as the matrix.

Two broad categories of Ecomaster products were tested.
(a) Individual devices which are used in the same fashion as a drinking straw and (b) Larger units which have a hand bulb pump action. The specifications for the products are listed in Table 2.

Table 2: Specifications of the Ecomaster products tested.

	Survivor	Survivor MP	Outdoor M1	Outdoor M1-PC	Outdoor 100	Outdoor* 100
Purification capacity (L)	100	700	375	475	750	
Pentapure I_5	Yes	Yes	Yes	Yes	Yes	Yes
Activated Carbon	Yes	No	Yes	Yes	Yes	Yes
Pentapure I_3	Yes	No	Yes	No	No	Yes
Length cm	14.5	14.5	16.5	16.5	20	20
Diameter cm	1.5	1.5	2.0	2.0	5	5
Weight g	21.0	23.0	49.0	42.0	500	
Flow Rate L/Min#	0.07	0.07	0.07	0.07	1	1
* This configuration is not normally available. Manufacturer's specifications for capacity and weight not available.						
# Manufacturer's specifications for the 'straw' units not available. Flow rate for the Survivor based on average drinking						

DIW was used within a pH range of 6.5 to 7.5, whereas SCW was used at

pH's 5,6,7,8 & 9. After each test the units were flushed with sterile deionised water. Tests were replicated on 3 separate days. There were usually 3 days between each test. Units were only tested using seeded SCW if they passed the specification (LCIS, 1975) when tested with seeded DIW.

3.1.1 Drinking 'Straws'

The biocidal capacity of the 'straws' was tested by drawing the seeded matrix through the straws with vacuum into a side arm flask. A survey of laboratory staff showed that the average intake of water, through the Survivor, was 100 mL in 1.5 min. The flow rate of fluid through the straws was therefore set at approximately 1 L/15 min. Five 1 litre portions of seeded matrix were drawn through into the sidearm flask, stirred, and an aliquot neutralised with sodium thiosulphate.

3.1.2 Outdoor 100

Two testing protocols were used for the Outdoor 100 devices. The I_5/C configuration was tested with the matrix seeded with washed cells. This is the protocol suggested by the manufacturer, and has no organic carry over from the broth cultures. The $I_5/C/I_3$ configuration was tested using the sterilising tablet protocol.

3.2 Palatability

The palatability of tap water, tap water passed through the Survivor MP (I_5) and tap water treated with a *Potable Aqua* tablet was evaluated on a taste panel by the Rating Method (ASTM, 1968). The tap water and *Potable Aqua* treated water were also drawn into a side arm flask as in 3.1.1, so that any taint derived from the silastic tubing used was common to all treatments. The panel consisted of 12 members who tasted each treatment on 4 occasions. The order of tasting of each treatment was designed to present all possible orders, to minimise bias. Panellists were requested to rate on a line scale with the ends verbally anchored by extremely poor and extremely good. The centre of the line was marked acceptable. Statistical analysis used Duncan's New Multiple Range test (ASTM, 1968), with tables of significance at the 5% level (Ecosoft Inc., 1990).

4. RESULTS & DISCUSSION

4.1 Biocidal Effectiveness

The results of tests on the Ecomaster range are presented in Table 3. Before each days testing the units were flushed with sterile DIW and this was tested for any carryover of bacteria. The unit that showed the most carryover was the Outdoor 100 (I_5/C). The bacteria isolated were not the seeded organism but were a *Pseudomonas spp.* This unit had previously had non-sterile deionised water at various pH levels passed to gauge the buffering capacity of the 'pentapure' active ingredient. It is postulated that the *Pseudomonas spp.* (tentatively identified as *Ps. cepacia* and *Ps. pickettit*) colonised the carbon filter. Initial flushes of the device with sterile DIW recovered levels as high as 10^8 CFU per Ml. Flushing with 2 L of sterile DIW, prior to passage of seeded water, was sufficient to reduce organisms to insignificant levels. The Australian agents for Ecomaster advised that this contamination had also been observed by Canadian workers (Personal Communication, Aquatec Pacific). The failures observed at pH's 6 and 8 were a combination of the seeded *Ps. aeruginosa* and contaminant *Pseudomonas spp.*

The 'straw' that showed the most promise, from an Australian military perspective, was the Survivor MP. This unit was capable of passing the Water Sterilising Tablet Specification (LCIS, 1975). It had lesser success when tested with the higher challenge of the SCW, but could see Service life in defined situations. Unfortunately combinations of the I_5, C and/or I_3 were not able to pass the specification.

The testing protocol supplied by Ecomaster Corporation suggests testing with washed cells to remove any organic load. Using this protocol they claim total bacterial kills at concentrations of approximately 10^9 CFU/mL. They estimate the organic load at this level to be 280-1120 ppm (mg dry weight per litre). Although emphasising that few studies have been conducted on the effect of organic loads on water purifiers containing I_5, the manufacturers cite the example of a study to test the 'giardicidal' properties of the resin. In this study (Marchin, 1990) 200 gallons of river water supplemented with 60 ppm Bacto Tryptone (Difco) was passaged through a purifier cup, and the device was found to be effective. The organic load of DIW water seeded with 0.5 Ml of each of the broth cultures is estimated to be 39 mg dry weight per litre. Composed of 38 mg/L nutrient broth carryover plus 1 mg/L of bacterial cells. The organic load of seeded SCW would be of the order of 208 mg/L (38 mg/L broth + 1 mg/L cells + 169 mg/L SCW). These values are within the organic load levels quoted by the manufacturer but do not take into account the iodine demand of the SCW.

It would seem that the Survivor MP represents the minimum mass of I_5 required to meet the LCIS specification. It would be reasonable to expect that an Outdoor M1 with only I_5 as the active ingredient, would also pass this specification.

Table 3: Compliance of the Ecomaster range to a 99.9% kill specification.

Product	Configuration	DIW Pass Rate			SCW Pass Rate		
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Survivor	$I_5/C/I_3$	0/5	0/5	0/5	NT	NT	NT
Survivor MP	I_5	5/5	5/5	5/5	3/5	5/5	1/5
Outdoor M1	$I_5/C/I_3$	5/5	5/5	0/5	NT	NT	NT
Outdoor M1-PC	I_5/C	1/5	0/5	0/5	NT	NT	NT
Outdoor 100#	I_5/C	5/5	5/5	5/5	5/5	5/5	3/5*
Outdoor 100	$I_5/C/I_3$	0/5	0/5	0/5	NT	NT	NT
# Tested in DIW and SCW inoculated with washed cells NT Not Tested because of failure in DIW * Failures at pH 6 and 8							

4.2 Palatability

The order of preference of the taste panel was tap water (mean 10.3; sd 2.9), Potable Aqua treated water (mean 6.3; sd 3.4) and I_5 treated water (mean 3.3; sd 2.3). There was a significant difference ($P<0.05$) between means for each treatment.

5. CONCLUSION

The Ecomaster range failed to meet the water sterilising tablet specification in any configuration other than I_5. This configuration failed the higher challenge of SCW, which had been used to identify the current operational use water sterilising tablet. Furthermore this configuration was found to be less palatable than iodine tablet treated water.

The Ecomaster range of products are not recommended for use by Australian Defence Force Personnel under operational conditions at this time.

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